upon the same slope have divided the masses of the rocks into large pieces, whilst the frequent earthquakes of the last months have given rise to large crevices in the slates and limestones. Already on September 9 it was perceived that the soil at the quarry was in slow motion, and a house situated immediately below was evacuated. Two days later, between five and six o'clock in the afternoon, it was seen that the forest on the slope of the mountain began to move, the trees being bent like a field of corn during a strong wind; they then rushed down, together with the rocks situated above the quarry, breaking up into thousands of pieces. This formidable stone avalanche reached the village, the trees were bent like straw, and the houses moved by the pressure of air pushed by the landslip. Men and houses were thrown on the opposite side of the valley, smashed against rocks, and buried by the landslip, which, as in the catastrophe of the Rossberg, crossed the valley and rose up-hill on its opposite side. The first landslip destroyed that part of the Elm Commune which is named Unterthal; but a second one followed immediately, destroying the village, and throwing the houses on the opposite side of the valley, one kilometre wide. The picturesque valley of Unterthal is now covered with a mass of mud, earth, and stones, thirty to forty metres thick, on the surface of which are seen blocks of the size of a house. The length of the landslip is about two kilometres, and the opposite side of the valley is covered with stones and blocks on a space of about 100 metres. The Sernft River, which flows in the valley, is barred by the *débris*, and has formed a small lake. The number of persons killed is about 160. Another small landslip occurred on the following day, and the slope of the mountain continues to be in motion. According to a report of Prof. Heim the remnant of the village is also threatened by a landslip, the Risikopf, or Grosskopf, being creviced and undergoing subsidences which render a landslip most probable, not so large, however, as the preceding one.

The *Times* Geneva correspondent writes under date September 19:—"According to the measurements and estimates of Prof. Heim, of Zurich University, who has just visited Elm, the earthslip of yesterday week, though less destructive of human life than the earthslip of Plurs and Goldau, probably exceeds in extent either of those catastrophes, great as they were. The portion of the Tschingel Alp which broke away from the parent mountain measured at its base 400 metres by 350 metres. The length of its projection outwards cannot, of course, now be ascertained. The length of what Prof. Heim calls the *débris* stream is 1500 metres, and varies in breadth from 300 to 400 metres. The distance of the extreme end of the stream from the place whence it broke away is 2000 metres. The extent of the valley bottom, which is tolerably even, covered by *débris* is computed at 570,000 metres, while the entire mass makes a total of 900,000 square metres. From the lower part of the valley to the upper joint of rupture the height is 620 metres. The fall was, therefore, a little over 2000 feet. The lowest estimate of the contents of the slip, according to the admeasurements of the engineers, is 10,000,000 cubic metres. It contains, says the Professor, enough stone to build two cities as large as Zurich, and the population of Zurich is 76,000. Some of the blocks, which are heaped 112 metres higher than the village of Elm, measure 1260 cubic metres, and are estimated to weigh 3300 tons. If the other earthslip, which is regarded as imminent, should take place, all that remains of Elm will be destroyed."

The heavy rains of the last weeks have caused several other landslips in Switzerland and Savoy. In the Upper Singine, in the canton of Freiburg, the soil is in slow motion in the valleys of the Gérine and Singine rivers, and a landslip of some importance has occurred at Planfayon. Another landslip occurred on September 2, close by Bernex village, on the slope of the Dent d'Och, and it is rather remarkable by the circumstance that it occurred in a broad open valley where one never would suppose the possibility of a gliding of rocks.

A further interesting result of the recent heavy rains is that the Lake of Bicune, which is somewhat lower than that of Neuchâtel, is now so full that its water runs into the Lake of Neuchâtel, inundating its shores.

PHENOMENA DEVELOPED BY HELIOSTATIC STAR-DISKS

A HELIOSTAT of the highest class is doubtless beyond the means of ordinary observers, but such an instrument as the one now described is readily obtainable. Three sets of achromatic lenses forming a focal power of forty at ten inches, or a miniaturing power of one-fortieth, are in general sufficient. If formed into a microscopic object-glass, the front is turned towards the sun. The glass then refracts a beautifully small star-disk, which, owing to the large angular aperture of the combination, remains steadily in view for several hours. The optical characters of this disk vary considerably with the quality of the lenses; practically a very fine one-quarter by Powell and Lealand produces disks of remarkable beauty and precision. In some cases a plane mirror is conveniently attached to reflect the oblique solar rays.

The instrument thus provides a stationary solar star-disk for continuous observation. No clockwork or machinery is required. The size of the disk is one-fourth of the sine of the solar diameter, or nearly 45-10,000ths of an inch.

A more brilliant form of surpassing effulgence is occasionally employed by a 3-inch lens placed before a right-angled prism. An aërial image of the sun thus produced outshines the electric light. These disks are viewed at a distance of ten feet.

It is proposed to describe first their use in microscopic research, and secondly for telescopic vision.

I. Microscopic Research

The Miniature Method.—A strong plate fitting the upper stage of the microscope by means of screws is pierced in the centre by an aperture carrying the "societies" standard screw, into which an objective can be firmly screwed. The stage motions then give readily the necessary adjustments for coincidence of optical axes. This is called the *stage-holder.* All previous methods of fixing the objective in the sub-stage have been abandoned; the necessary steadiness being almost unattainable.

Phenomena of Heliostatic Star-Disks produced by the One-quarter.—Stage-holder armed with an inverted 1-32nd water-immersion. The miniature of the star-disk is now viewed microscopically with a 1-16th immersion. When both of these objectives are adjusted for the most brilliant vision, *distant foliage is distinctly visible.* A flag-staff carrying the Union Jack 180 yards away displays its double cross. The fine lightning-rod surmounting it is distinctly visible. Houses on a hill glisten in the sunshine; but conspicuous above all is the minute solar star-disk blazing with all the glory of a midday Sirius at the open window-sill.

Here the favourite tests for telescopic precision come richly into play. A minute brilliant bead surrounded by the most intensely black ring—the more wonderful as the brilliance seems to heighten its rare and beautiful delicacy and blackness—comes up and plays into expanding coloured rings on each side of the principal focal point. (The delicate beauties of this exquisite phenomenon cannot well be seen without an exceedingly delicate fine focal adjustment.) The focussing wheel (constructed for the lightest contact) is divided into 132 parts; twenty-six give a focal plane the 1000th of an inch deeper or higher,

but a tenth part of this, or a change of focus of the 10,000th of an inch, changes the appearance of the magnified star-disk. These changes, so vivid and sudden, produce a lively impression of the minuteness of the wavelets of light which generate these diffractive phenomena.

The diameter of the brilliant disk, as miniatured, is about the 1-20,000th of an inch; the jet black ring in which it appears set, and indeed well set-off, is about 1-100,000th thick. Slight changes in the focus, but especially slight changes in the corrections of the observing and miniaturing glasses, produce a new order of phenomena, full of a significant meaning and practical import. The minimum visible is perpetually forcing itself upon the observer's attention. The lightning-rod (here visible) 6000 inches away, is miniatured 600 times smaller than at 10 inches by the 32nd objective, which then would diminish an object only 320 times. The rod is therefore depicted nearly 200,000 times smaller. It is exactly half an inch in thickness; its size therefore in the miniature is 1-400,000th.

As the evening light faded away a long row of gas-lights reaching half a mile came into view in pretty perspective, the more distant being very slightly out of focus (six divisions). The 32nd objective required to be advanced the 4000th part of an inch for the distant light. In this case the miniature was produced by a Zeiss 1-32nd, and viewed by another 32nd by the same maker. The lowest eye-piece is employed and a shortened eye-tube. A single glance at these microscopic landscapes satisfies the observer at once as to the quality of the instruments of observation. Achromatism is seldom attained without generating a whitish haze, the inevitable accompaniment of residuary spherical aberration. This haze is an invaluable indication.

The haze observed in miniatures examined by high magnifying power is an invaluable indication of spherical residuary aberration. The method gives a cruel test of the optician's art. Its discovery led to the subject coming before the Royal Society and its being embodied in their *Transactions*. When first seen it was exhibited as a strong yellow fog. The announcement of it occasioned the greatest surprise to the distinguished makers of a "very fine" set for the writer. In most cases the higher the angular aperture the denser was seen the fog. The following is quoted: "Mechanical arrangements are shown by diagrams, Figs. 1, 1*a*, plate LII." (*Phil. Tr.*, vol. ii. 1870, p. 592).

"*Experiment I.*—Miniature of a small thermometer, the ivory scale being graduated 24° to the inch. A power of 300 diameters: low eyepiece 'A' and objective of one-eighth focal length (made expressly for Podura testing) was applied to view the miniature formed by a one-sixteenth objective. The following appearances were carefully noted at the time of observation:—

"*Result.*—The sparkle of light on the bulb of the instrument, the graduation, and the mercurial thread within the glass are invisible, obscured by a nebulous yellow fog which no objective adjustments are able to dissipate."

In consequence of this unexpected discovery regarding the quality of a "very fine" one-eighth, it was returned to the opticians, to their surprise, for better compensation. After improvements a very slight nebulous yellow cloud now only remained.

A new fact now came up. A *miniature* formed by an imperfectly corrected glass is comparatively free from the aberration shown by the same glass used as a microscope. Thus, viewed by a good glass, the miniature of an inferior one bore wonderful magnification by an excellent objective.

In innumerable objects surface markings are shown only: with no perspective and with no foreshadow of deeper structures such objects are opaque. But if transparent, the foreshadow of deeper structures confuses the appearance of surface; strange eidola are generated difficult of interpretation and dispersion. A series of star-disks in deeper foci intermingle their diffractions into beautiful forms.

The strong fact that these diffractions of a given disk are wholly developed towards the eye of the observer, or wholly developed beyond the true focal plane, according as the correction of the glasses is over-wrought or under-wrought, reveals an infallible clue to many spurious effects. This method therefore more severely tests the observing instrumentation than the miniature.

The following experiment, arising out of the phenomena in course of observation, is quite a microscopic study in itself:—

Experiment.—Miniature of garden view formed by a 1-30th plano-convex lens and examined by a microscope armed with 1-8th giving 400 diameters.

Result.—Landscape dark and hazy. But upon using the same power (400) with a deep eyepiece and a half-inch objective, there started forth an exquisite picture brilliantly lit up. Even the foliage glittering in the sunlight was sharp, clear, and decisive, the details being marvellously displayed. This large increase of light with diminished observing angular aperture is at first sight astonishing.

It is to such causes doubtless that the microscopic world so long disputed whether the markings on diatoms were depressions or elevations. The earlier plates of such objects, as given by Quekett, teem with eidolic varieties of form. It was thought impossible to resolve them, as it was called, without complicated stops, which in fact shut off the unsuspected residuary aberration.

But it is necessary to pass on to the *fundamental circular spectrum* of a minute solar disk. A simple plano-convex lens of half an inch focus is placed on the microscopic stage and made to form a miniature of the prism star in the field of the microscope. If the experiment be properly conducted, forty gorgeously coloured rings may be counted. I have frequently examined these phenomena with a power of 1000 diameters. Above the best focal point is a bright fog; below are seen the glorious diffractions. The sun, as far as it could be made out, was a spurious disk nearly 6-100,000ths of an inch; the first black-ring, the blackest thing I ever beheld, was nearly the 1-50,000th. Each ring beyond appeared exactly of the same breadth—nearly the 1-16,000th.[1]

If now an over-corrected lens were substituted, the diffraction rings ascended and the nebulosity descended: they exactly changed positions as regards focimetry. The conclusion follows that all brilliant objects present diffractions above or below the true focus according as the observing instrument is over- or under-corrected by means of the usual screw collar adjustment.

In this way the same object, especially diatoms, may be made to take several very deceptive forms, because spuriously diffracted. The same is true of all brilliantly illuminated transparent structures.

The intersection of an infinite number of cones of light converging to different points of the axis here produces the well-known interference extinction of undulation evolving precisely-formed rings of darkness. The simple lens, in these observations, develops circular spectra, as being formed by an infinite number of prisms.

An important outcome of this phenomenon is the unerring test (here presented by a simple single convex plane lens) of the highest possible order, as to the *quality*

[1] The contemplation of these phenomena, utterly eclipsing in their brilliant beauty and precision of form the fainter diffraction phenomena described by Sir John Herschel as amongst the most gorgeous in nature, astonishes every beholder. Some little skill is required in gradually toning down the excessive, I might say painful, glories of the appearances—lengthening the eye-tube; glass tinted wedges (a single field-lens of a Hyghenian as eyepiece produced a spectrum apparently twelve inches in diameter, measured with the left eye by rule laid on the stage), or by camera.

or inferiority of the observing microscope. Extreme steadiness and a *particularly* delicate fine focussing adjustment are indispensable for successful observations. It is impossible here to detail them.

A plain silvered mirror of the old style must be discarded as a solar reflector; prismatic internal reflexion or reflexion from a metallic surface is indispensable for producing purity of spectra.[1]

But it is when superb objectives are placed as it were eye to eye, that the finest observations can be made (especially when both are used with their noses inserted in the proper immersion fluid for observing landscapes) on distant objects.

The extreme delicacy of the change in focal planes of vision is charmingly illustrated by observing with a good 1-8th the miniature of two brilliant points, the one 200 inches, the other 201 inches away in the same line. If the miniature is formed by a simple lens, theoretically the focal images of these star-disks would be separated by an interval of 2-10,000,000ths of an inch for a 1-10th lens, *perfectly* aplanatic.[2]

These disks, by their rapid change in appearance, give the most exquisite means of determining focal changes in the microscope. Thus for a focal depression of 7-10,000ths of an inch a change took place from *one* pure jet black diffraction-ring round central disk to eleven rings. The rings changed visibly for a focal depression of 100,000th of an inch.

The greatest confusion has existed regarding the terms penetration, definition, and resolution. The study of star disks miniatured by surpassingly well-corrected glasses furnishes the observer with a new order of facts upon which irrefragable conclusions can be founded.

A telescope of very fine quality should have a focus of extreme delicacy. One whose change of focus by 1-10th of an inch produces little or no effect upon the "definition" is contemptible. In the same manner the quality of microscopes may be estimated by the striking effects of a minute focal change. The planes of focal vision, it will be found, vary extremely, their interval varying according to a function of several complex factors.

The prism-heliostat already described is well represented by an Amici prism. Small bulls-eye lenses, laid with the convex surface upwards in the sunshine, present two brilliant images of the sun at a distance of 200 inches. They are of unequal brilliancy. A row of these placed in a line with the axis of the instrument,[3] and somewhat tilted, so that the star-disks may be all seen at once, will develop a series of fine microscopic effects, dependent on the corrections of the systems in use and the immersion-fluid in which the noses of the glasses are inserted (sometimes a piece of adherent glass cover intervening, as the water tends to run off). If a 1-33rd objective be employed to miniature them, and a 1-16th to observe them, extraordinary fine excellence insures a perspective almost as clear as an opera-glass. The minute double stars—which may be brought as close as we like by change of the angle of position of the instrument with the sun's azimuth—produce a variety of diffraction rings, mingling, crossing, and breaking up each other in a manner that could hardly be suspected during the telescopic observation of real double stars. Seldom can a bright landscape be attained without leaving some little outstanding colour. If that be destroyed by changing the glasses or corrections immediately, *all black objects look grey*, and the grey becomes lighter as the colour nearly vanishes. The rest of the view is charged with a thin greyish-white nebulosity, the sure indication—as already described—of residuary aberration. Just within the best focus an exquisite little dark-grey bead margined with black—much less than the primary brilliant disk (half its size)—may be discovered by close attention and a particularly well-adjusted focussing apparatus.

[1] Some indications of quality in microscopes:—(1) Confused mass of spurious disks oddly arranged; (2) Beauty of rings utterly marred; (3) Very few rings definable; (4) Spectrum notched, grained, and spotted; (5) Systems of excentric rings dark and coloured, much confused; (6) An "engine-turned pattern" mottled and degenerated; (7) Achromatism and freedom from spherical aberration in all cases found incompatible. The universal presence of some residuary spherical aberration is demonstrated by several irrefragable proofs in all the finest-made modern glasses.

[2]
First conjugate focus distance	0·10005002
Second " "	0·10004977
Interval between foci	0·00000025

[3] The miniature-making objective and observing microscope are both placed horizontally.

In observing these interesting phenomena it will be seen that larger[1] and smaller spurious disks are formed according to the curvatures of the bulls-eyes; but there is one minimum size; and these, when contiguous, illustrate diffraction spectra in a brilliantly instructive form.[2]

Upon a proper arrangement, putting the bulls-eye and the instrument nearly in a line with the sun's azimuth, a superb representation of the double star, Castor, is seen, the fainter star being that caused by internal reflection. Intensely black diffraction rings round each, and several fainter ones, fewer as the quality of instrumentation is raised. Perfect roundness can only be attained by exact coincidence of the optical axes of the system. Very slight obliquity (even half a degree) causes the rings to overlap and bulge on one side. Much obliquity gives rise to glorious curves of the three orders of the conic sections, of wondrous beauty and precision in effulgent colours.

Mercurial globules near the microscope exhibit very delicate and complex forms when similarly miniatured, as minute solar disks, in sunlight.

Experiment.—An optician's gauge comprising half a dozen lenses of standard foci 1″ to 1-6″th, lying in the sunshine, miniatured star disks by reflection (see (1) in figure. Inferior objective 1½ inch examined with fine power of 1000. Two brilliant crimson disks in contact expanding within focus to an oval ring of deep crimson beads.

Experiment.—If the image of the sun be received on white paper from a small lens placed at various degrees of obliquity peculiarly beautiful forms are seen fringed with colour. When the lens is sufficiently minute these spectra exhibit to the microscope exquisitely-arranged curves in jet-black lines; circular elliptic parabolic and hyperbolic, with inexhaustible variety, according to the focal plane of vision and obliquity. Heliostatic star-disks most successfully exhibit these unique phenomena. The superiority of these phenomena to anything telescopic of the sort is insured by the absence of atmospheric disturbance within so short a distance. They are all under instantaneous control.

The limits of human vision among so many bright points are patent enough. So long as there is bright sunshine every glittering point obscures, I might say utterly effaces, the finer traceries of detail. A passing cloud, however, brings them all out with astonishing fidelity. Brilliant diffraction is thus demonstrated to be incompatible with exact portraiture. The limit is reached in brilliant sunshine by the diffraction disks obliterating the very objects which produce them. This limit is well measured by the diameter of the smaller disks seen in contact, which in white compound light generally appears by micrometric measurement to be between the 1-80,000th and 120,000th of an inch in the microscopic field.

We need not be surprised at this variation: the undulatory theory of light gives *one* size only. Yet, as the spurious disk by theory is shaded off *gradually* into the

[1] Luckily the image of the sun is very nearly the hundredth part of the focal length of the lens employed. If a bulls-eye of 1-inch focal length be employed at 200 inches, and a miniature be produced by a 1-8th, diminishing it 20 × 80, or 1600 times, the observed image of the sun would theoretically be 1-1600 × 100 = 1-1,600,000 less than one millionth of an inch. It should be noted that if the primary axial image of the sun be too large, no diffraction spectra will be developed at 200 inches, unless very deep miniature-objectives be employed.

[2] The January sun image formed by 1-inch lens is 1-106th inch.
The April " " " 1-108th inch.
The July " " " 1-109th inch.

first intensely black first ring, fainter stars telescopically show smaller disks.

But whilst a close row of spurious disks are seen to coalesce and obliterate themselves if too close, and become continuous as a thick luminous line—the necessary effect of bright diffractions—duller objects devoid of brilliance are seen of amazing minuteness of tracery.

Example.—The rungs or rounds of a ladder resting against a house half a mile off were distinctly seen when miniatured down to 1-1,000,000th of their actual size, *i.e.* considerably less than 1-1,000,000th of an inch. This feat was accomplished by an immersion 1-32nd by Seibert, which diminishes an object 30,000 inches away just about 1,000,000 times. The bane of minute microscopic research is thus seen to essentially consist of a combination of diffraction with the haze of aberration.

A blue glass evidently diminishes the diffraction phenomena; so do neutral tints. This exactly tallies with the shrinking of spurious telescopic disks during haze and sky-clouding. These facts forcibly point out the great advantages of observing in mild light. In further support of this the writer has thus effected several very difficult resolutions—in the "Ultima Thule" of microscopic investigation glare is the prolific parent of many fallacious interpretations.

These studies have encouraged the writer to continue a research into the limits of human microscopic vision. In the case of bright illuminations the limit is evidently reached at once. A minute refracting spherule thus forms a bright focal point which itself exceeds by expansion into a spurious disk, the diameter of the spherule producing it. Down to a certain size a focal image is discernible. A very interesting study is given by the solar star-disks presented by receiving the rays from the heliostat after passing through a beetle's eye placed on the field of view on the stage of the microscope.

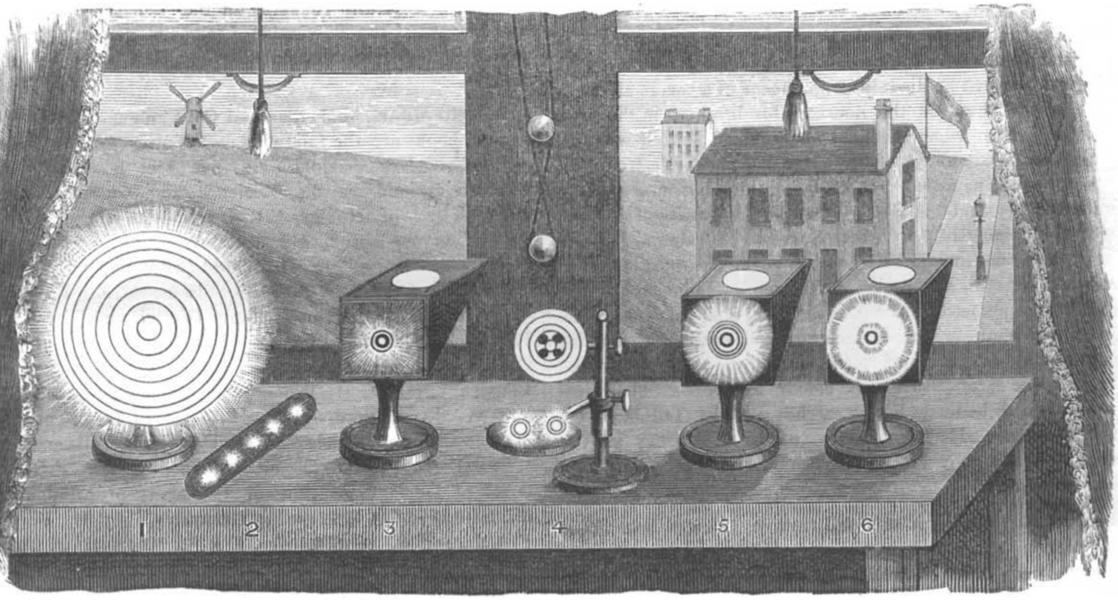

FIG. 1.—Taking the objects from left to right, a representation is given of a miniature magnified a thousand times linear and the various appearances of the heliostatic star disks with slight changes of focussing. 1. Large diffraction rings: *fundamental spectrum* given by a plane convex lens ⅓ inch focal length placed on stage of microscope. Forty rings have been counted. 2. Optical gauge: various lenses showing spurious disks with minute diffraction rings similar to those on the "bulls-eye" in centre of picture. 3. Intensely clear bright star disk produced by very perfect instrumentation. 4. A cross given by imperfect glasses. 5. Larger expanding rings, the miniature or observing glasses being either under or over-corrected. 6. The finest and clearest spurious disk attainable.

NOTE.—The house on the hill distinctly seen in this case of very finely corrected glasses. A miniature formed by a very fine 1–32nd gives the distant house and window nearly in the same focal plane.

Until the sun shone the window appeared miniatured in each eye. It seems curious to measure the focal length. By measuring the images this was found to be 1-1000th of an inch, giving enormous magnification for ordinary vision.[1] The solar disk, however, appeared spuriously enlarged.

More wonderful diffraction-phenomena are developed by different treatment. A half inch condenser-objective was inserted between the coleopterous eyes and the heliostat—behind or beyond the stage. The solar disks developed then appeared severely beautiful. No such wonderfully sharp black rings are even viewed telescopically. These phenomena are in order of focal classes—

1. Intensely black truly formed rings.
2. Hexagonal black patterns on a brilliant ground.
3. Three such hexagonal rings to each eye-facet.
4. Five such finished off with extremely rich Scotch plaid patterns, highly coloured.

G. W. ROYSTON-PIGOTT

NOTES

THE Delegates of the Clarendon Press will shortly publish an "Elementary Treatise on Electricity," by the late Prof. James Clerk Maxwell, edited by Mr. W. Garnett, formerly Fellow of St. John's College, Cambridge. The book was commenced about seven years ago, but its completion was prevented by the author's other engagements; so that during the last three years of his life very little was added to the work. After his death the first portion of the manuscript, on Statical Electricity, was

[1] Their focal length was measured by selecting a well-defined object, as a red brick house, carefully measuring micrometrically a given part of it, and then measuring an image of the same thing in a known lens.

If d be the distance of the object from its image, m the size of its miniature, M the size of the object,

$$f = d \times m \div M.$$

A convenient formula for estimating the focal length of a small lens was given by me in the *Phil. Trans.* If it is found to magnify m times at a distance *between object and image d*, and if m be considerable,

$$f = \frac{d}{m+2}, \text{ more accurately } = \frac{d}{m + \frac{1}{m} + 2}.$$